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SURGICAL ENDOSCOPY
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A prospective case-matched comparison of clinical and financial outcomes of open versus laparoscopic colorectal resection

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Abstract
Background: We aimed to assess the clinical outcomes and costs associated with laparoscopic resection within an elective colorectal practice.
Method: Over a 12-month period data were prospectively collected on patients undergoing elective colorectal resection under the care of a single consultant surgeon. Thirty patients undergoing laparoscopic colorectal resection were case-matched by type of resection, disease process, and, where appropriate, cancer stage to patients having open surgery. A cost analysis was carried out incorporating cost of surgical bed stay, theater time, and specific equipment costs.
Results: In the 30 patients having laparoscopic resection, a conversion rate of 13% was observed. Surgery was performed for colorectal cancer in 83% of patients, and 53% of resections were rectal. No significant differences were found in age (65 versus 69 years, $p = 0.415$), BMI (27.4 versus 26.1, $p = 0.527$), POSSUM physiology score (16 versus 16.5, $p = 0.102$), American Society of Anesthesiologists (ASA) grade (2 versus 2, $p = 0.171$), or length of theater time (160 min versus 160 min, $p = 0.233$) between the laparoscopic and open patients. Hospital stay was reduced in the laparoscopic group (5 versus 9 days, $p < 0.001$). Average cost of surgical equipment used for a laparoscopic resection was greater than for open surgery (£912.39 versus £276.41, $p = 0.001$). Cost of hospital stay was significantly less (£1259.75 versus £2267.55, $p < 0.001$). Cost of operating room time was similar for the two groups (£2066.63 versus £1945.07, $p = 0.152$). Overall no significant cost difference could be found between open and laparoscopic resection (£4560.9 versus £4348.45, $p = 0.976$). More postoperative complications were seen in the open resection group (14 versus 4, $p < 0.001$).
Conclusions: Intraoperative equipment costs are greater for laparoscopic resection than for open surgery. However, benefits can be seen in terms of quicker recovery and shorter hospital stay. Laparoscopic surgery is a financially viable alternative to open resection in selected patients.

Key words: Laparoscopy — Colorectal surgery — Cost analysis

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Laparoscopic colorectal resection was first described in 1991 [7], however, early reports of port site recurrence [1, 15], concerns about safety, and questions about long-term survival led to limited acceptance of this new technique.

In May 2000 a systematic review into the effectiveness and cost effectiveness of laparoscopic versus open colorectal surgery concluded that there was no evidence of long-term risks or benefits from the laparoscopic approach compared to open surgery. However, laparoscopic surgery was more expensive than the open equivalent [18]. More recently, results of large multicenter randomized controlled trials comparing laparoscopic with open surgery for colorectal cancer have been published [2, 3, 6]. These have largely dispelled concerns regarding oncological safety of laparoscopic surgery and have suggested short-term benefits in terms of more rapid patient recovery with fewer complications, less pain, and shorter hospital stays.

The necessary learning curve for this new technique is understandably associated with longer operating times and therefore more operating room expense than open surgery. Additionally the use of specialized and disposable laparoscopic equipment can become costly, putting further strain on limited theater budgets. Despite an increasing body of evidence demonstrating potential advantages of laparoscopic resection, learning curves and the time constraints on busy theater lists, together with costly laparoscopic equipment, may be limiting its use. In the present study, we aimed to prospectively compare elective laparoscopic and open colorectal resections in single surgeon's practice in terms of theater

Table 1. Summary of demographic factors and physiological scoring comparisons for patients undergoing laparoscopic and open resections

Parameter	Open surgery $n = 30$	Laparoscopic surgery $n = 30$	p Value
Age (years)[a]	69 (11.8)	65 (13.8)	0.415
Gender (Male:female)	18:12	16:14	0.602
BMI (kg/m^2)[a]	26.05 (5)	27.43 (5)	0.527
ASA grade[b]	2 (1–4)	2 (1–3)	0.171
POSSUM physiology score[b]	16.5 (12–30)	16 (12–23)	0.102
POSSUM operative score[b]	16.5 (12–30)	14 (9–21)	<0.001
POSSUM predicted morbidity (%)[b]	49 (20–87)	32 (9–61)	<0.001
Rectal resection (%)	53	53	1.0
Cancer resection (%)	83	83	1.0

[a] Values expressed as mean (standard deviation)
[b] Values expressed as median (range)
BMI: body mass index; ASA: American Society of Anesthesiologists

time, clinical outcome, and direct (specific and overall) costs.

Methods

Between September 2003 and October 2004 data were prospectively collected on all patients undergoing elective colorectal resection under the care of a single consultant colorectal surgeon. This time period covered the evolutionary stages of the colorectal laparoscopic service development within the department of surgery, and, as such, both laparoscopic and open resections were routinely performed. Laparoscopic resection was offered to all patients in the absence of radiologically proven invasion into abdominal wall/adjacent organs, multiple previous abdominal procedures, or low rectal tumor (if APR was not the planned procedure). Open surgery was still regularly performed in response to patient choice and perceived time-management issues The group of patients who had no contraindications to laparoscopic surgery but elected to undergo open resection were used as the case-matched comparisons.

All operations were performed by a single consultant, who had experience in both laparoscopic (>100 previous laparoscopic resections) and open colorectal surgery. A single assistant (surgical trainee) was required for all cases. All specifically laparoscopic equipment used was disposable.

Thirty patients undergoing laparoscopic resection were case-matched to open surgery patients by type of resection, disease process, and tumor stage. Clinical data recorded included patient age, body mass index (BMI), American Society of Anesthesiologists (ASA) grade, POSSUM score, reason for surgery (benign or malignant disease), type of resection (colon or rectal), length of procedure (timed from patient's placement on operating table to completion of skin closure), operative blood loss, blood product requirement, return of lower gastrointestinal function (time to first flatus and first bowel movement), return of upper gastrointestinal function (time to tolerating diet), complications, mortality, hospital stay, and readmission rate. Postoperative care was standardized for patients in both groups, who were looked after by the same clinical and nursing teams on the same surgical wards. The postoperative care regimen included early mobilization (day 1), early feeding (fluids from day of surgery, diet from day 1 post-surgery), and daily physiotherapy. The surgical team assistant recorded complications daily after the ward round. Patients were deemed fit for surgical discharge once they were walking without assistance, had adequate pain control with simple oral analgesics, were tolerating a normal oral intake, and had return of bowel function. Postoperative pain control was routinely provided by epidural/patient-controlled analgesia for the first 48 h post-surgery, with oral analgesia thereafter.

A cost analysis was carried out, incorporating cost of surgical ward stay, cost of theater time, cost of blood products, and specific equipment costs. Costs were calculated using the summation of total costs for each individual patient.

Data were analyzed using the SPSS version 10.0 for Windows. Normally distributed data expressed as mean and standard deviation were compared using Student's t-test for unpaired samples and the Mann-Whitney U-test for analysis of other continuous data expressed as median and range. Categorical data were compared using the chi-square test. A p value of <0.05 was considered statistically significant.

Results

Data were collected and compared on 60 patients undergoing elective colorectal surgery. Thirty patients underwent laparoscopic resection, and 4 procedures were converted to open surgery (13%). Reasons for conversion were, to aid removal of large tumor mass following complete laparoscopic dissection (1 patient), T4 tumor invading adjacent structures (2 patients), and inadequate visualization (1 patient). All results were analyzed on an intention-to-treat basis.

Resections were performed for colorectal cancer in 83% of patients, with distribution of colon to rectal resection being similar for each group. No significant differences were found in specific patient characteristics or length of surgery (Table 1).

No significant difference was found in POSSUM physiology severity score or POSSUM operative severity score, and therefore POSSUM-predicted morbidity was affected by the significant reduction in perioperative blood loss in the laparoscopic patients. This gave more favorable predicted outcome scores for laparoscopic surgery (Table 1, Table 2).

Patients who underwent laparoscopic resection were fit for discharge a median of 4 days earlier than the open surgical patients (Table 2). Although no difference was seen in return of lower gastrointestinal function, patients who had laparoscopic resection were able to tolerate normal oral intake earlier. The overall postoperative morbidity was higher in the open resection patients (14 versus 4 patients, $p < 0.001$) (Table 3). When looking at the specific costs of procedures (Table 4), the additional and specific equipment used in laparoscopic resection was significantly more expensive than equipment used for open surgery (costs of equipment/materials that were common to both types of surgery were not included in the analysis). In contrast, blood product costs were higher after open resections. Cost of time spent in theater was similar for both procedures . The "hotel" costs, i.e., cost of a patient's stay on a general surgical ward, were significantly less for those patients having laparoscopic resection.

Table 2. Summary of perioperative and postoperative clinical parameters

Parameter	Open surgery	Laparoscopic surgery	*p* Value
Length of operation (min)[a]	160 (80–240)	160 (70–330)	0.233
Perioperative blood loss (ml)[a]	528 (100–2435)	100 (100–640)	<0.001
Blood transfusion requirement (number of units given)	18	0	<0.001
Time to first flatus (days)[a]	2 (1–5)	2 (1–6)	0.951
Time to first bowel movement (days)[a]	4 (1–12)	3 (1–21)	0.640
Time to tolerating diet (days)[a]	3 (1–12)	2 (1–10)	0.041
Time until fit for surgical discharge (days)[a]	9 (5–17)	4 (3–45)	<0.001
Actual hospital stay (days)[a]	9 (5–20)	5 (3–45)	<0.001

[a] Values expressed as median (range)
Note: Length of operation was timed from placement on operating table to closure of skin incision; time to tolerating diet was defined as consumption of >50% of each meal in a 24-h period

Table 3. Summary of postoperative complications, mortality and re-admission rate following laparoscopic and open colorectal resection

Complication	Open surgery	Laparoscopic surgery	*p* Value
Wound infection	1 (3%)	1 (3%)	
Perineal breakdown	1 (3%)	0 (0%)	
Pulmonary infection	3 (9%)	0	
Urinary infection	3 (9%)	0	
Retention	2 (6%)		
Anastomotic leak	0	1 (3%)	
Nausea/vomiting ileus	2 (6%)	1 (3%)	
Other	1 (3%)	0	
Death	0	1 (3%)	
Readmission	1 (3%)	0	
Overall	14 (47%)	4 (13%)	<0.001

Discussion

We found patients undergoing laparoscopic colorectal resection to have less perioperative blood loss, earlier return to normal oral intake, fewer postoperative complications, and fit for earlier hospital discharge than their open surgery counterparts. Cost analysis did not show any significant difference in total treatment costs for either mode of surgery. Although we recognize that our study involved only small numbers of patients, the findings provide encouraging support for both the clinical benefits and the cost savings associated with laparoscopic colorectal resection. The study findings complement existing evidence in the literature from both large single center studies and multicenter randomized controlled trials. Although the specific equipment costs of laparoscopic surgery are significantly greater than those of open resection, this expense is offset by a significant reduction in the overall cost of hospital stay.

Although this was a non-randomized study, patients were case-matched and no significant differences were found in age, ASA grade, POSSUM physiology score, distribution of colon to rectal tumors, and type of surgical resection. Our conversion rate of 13% is comparable to the published data, with reported conversion rates varying from 4% to 28% [5].

The MRC CLASICC trial reports a median hospital stay of 9 days following laparoscopic resection, giving a stay reduction of 2 days compared with open surgery [6]. Similar results from the COLOR trial study group and from Leung et al. give mean stays of 8.2 days for laparoscopic surgery [3, 11]. All these studies however, report comparatively long postoperative stay following laparoscopic resection when compared to other research groups, who report median stays of 5 days following laparoscopic resection [2, 10]. Many of these studies, however, have excluded patients undergoing rectal resection, a factor that may influence length of hospital stay and time to recovery [2, 3, 10]. Our study included patients having either colon or rectal resection; indeed, the proportion of patients undergoing rectal resection was 53%. This may have implications with regard to operating time, morbidity, postoperative stay, and mortality. Despite this possibility, our finding of fitness for discharge and actual stay for laparoscopic patients being 4 and 5 days, respectively, is more in keeping with the latter studies of laparoscopic colectomy.

Many studies have found laparoscopic surgical resection to be associated with significantly longer operating times compared to the open equivalent [2, 3, 6]. Lezoche et al. compared laparoscopic with open hemicolectomy in a prospective non-randomized study. Although they found laparoscopic surgery to take longer, they further stratified their results to compare operating times for the first 30 cases and the last 20 cases, and they found that as their laparoscopic experience increased, the operating times significantly reduced, becoming closer to those of open resection [12]. We used time of placement on the operating table as the start of procedure—this allowed inclusion of port insertion and set-up of equipment—in the operating time for laparoscopic surgery. End of operation was recorded as time of completion of skin closure. In our study no statistically significant difference in length of surgery between the open and laparoscopic patients was found. While this observation is limited by patient selection in the non-randomized setting, all resections were performed by a surgeon experienced in both the open and laparoscopic techniques, demonstrating that with training and experience, operating time may not be a significant issue.

In some economic studies, longer operating time led to significantly increased operating room cost for laparoscopic resection [13, 14, 17], and operating time cost combined with equipment expense has been shown to make laparoscopic resection more expensive than open

Table 4. Summary of cost breakdown and overall costs for laparoscopic and open Resections (surgical bed day £251.95; operating theater hour £729.40; blood transfusion unit £121.80)

Cost per patient	Open surgery	Laparoscopic surgery	*p* Value
Equipment[a]	£276.41 (77.07)	£912.39 (186.41)	< 0.001
Theater time[b]	£1945.07 (972.5 – 2917.6)	£2066.63 (972.53 – 4011.7)	0.152
Blood products[a]	£73.08 (122.22)	£0 (0)	< 0.001
Surgical bed[b]	£2267.55 (1259.75 – 5039.0)	£1259.75 (755.85 – 11337.75)	< 0.001
Total cost	£4560.90 (2636.1 – 7657.1)	£4348.45 (2856.5 – 14808.8)	0.976

[a] Values expressed as mean
[b] Values expressed as median

surgery [16]. However, the majority of studies have shown that, despite more lengthy operations and expense of instruments, the clinical improvements seen allow laparoscopic resection to be a cost-effective alternative to open surgery [4, 13, 14, 19].

Laparoscopic resection has been shown to significantly reduce postoperative analgesic requirement [2, 3, 19]. We did not directly measure administration of analgesia, but the shorter length of stay is an indirect reflection of adequate pain control, as pain controlled with simple oral analgesia was a component of our discharge criteria.

We found patients in the laparoscopic group were able to tolerate a normal oral intake earlier than those patients who had undergone open resection. In the published randomized trials, earlier resumption of gastrointestinal function is a consistent feature following laparoscopic resection. Indeed, earlier oral nutrition together with resolution of ileus has important implications in terms of a patient's fitness for discharge.

Reduced postoperative complications have been reported following laparoscopic resection in some studies [10]; however, multicenter randomized controlled trials have failed to show any difference in both in-hospital and post-discharge morbidity between laparoscopic and open surgery [2, 3]. This study was underpowered to allow valid statistical comparisons of individual complications, although the observed incidence of postoperative morbidity appeared to be less in the laparoscopic group. Although we did not take into account specific costs of complications and their management, this may be indirectly reflected by the corresponding increase in hospital stay associated with postoperative complications and slower resumption of diet in the presence of nausea/ileus.

Blood loss and blood product requirement in laparoscopic compared to open surgery is unclear, with some studies reporting reduced estimated blood loss [3, 9] and others suggesting that the blood loss is comparable [8]. It has however, been shown that in case-matched patients, when comparing blood loss, preoperative and postoperative hematocrit and transfusion requirement, a clear advantage of laparoscopic surgery is evident [9]. We found significantly reduced blood loss and corresponding blood product requirements in our laparoscopic patients. Increasing cost of stored blood, together with the laboratory costs associated with cross-matching have obvious financial implications in favor of laparoscopic surgery.

Although operating times are undoubtedly longer during the initial laparoscopic learning curve, we have demonstrated that, with increasing operator experience, operating times become comparable. Equipment costs are greater for laparoscopic resection, although, these could be reduced by the use of nondisposable instruments. Despite the proportionately higher equipment costs, the improvements in clinical recovery and shorter hospitalization time make laparoscopic resection financially competitive when compared with open surgery. Proficiency in laparoscopic colorectal techniques requires adequate training and resources. However, the improvement in patient outcomes seen in our laparoscopic patients, together with comparable operating room times and overall cost, suggests justifiable endpoints for laparoscopic resection in both clinical and financial terms. Concerns regarding increased cost and long operating time should not therefore adversely influence the development of a laparoscopic colorectal practice.

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